JC18 Rec'd PCT/PTO 05 DEC 2001

FORM PTO-1390 (Modified) (REV 11-2000) U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER **10541-824**

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 10/009504

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB00/02152	**June 5, 2000**	**June 5, 1999**

TITLE OF INVENTION
HEAT EXCHANGER TUBE

APPLICANT(S) FOR DO/EO/US
Garry Royston Fish

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   a. ☒ is attached hereto (required only if not communicated by the International Bureau).
   b. ☐ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☐ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☐ is attached hereto.
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☐ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☒ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☐ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☒ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☒ Certificate of Mailing by Express Mail
23. ☒ Other items or information:
    WIPO Publication No. WO 00/75593 A1

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 10/009504	INTERNATIONAL APPLICATION NO. PCT/GB00/02152	ATTORNEY'S DOCKET NUMBER 10541-824

24. The following fees are submitted:.

BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :

		CALCULATIONS	PTO USE ONLY
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than months from the earliest claimed priority date (37 CFR 1.492 (e)).	☐ 20 ☒ 30	**$130.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	25 - 20 =	5	x $18.00	**$90.00**	
Independent claims	3 - 3 =	0	x $84.00	**$0.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	

TOTAL OF ABOVE CALCULATIONS =		**$1,110.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.		**$0.00**	
SUBTOTAL =		**$1,110.00**	
Processing fee of **$130.00** for furnishing the English translation later than months from the earliest claimed priority date (37 CFR 1.492 (f)).	☐ 20 ☐ 30 +	**$0.00**	
TOTAL NATIONAL FEE =		**$1,110.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**	☐	**$0.00**	
TOTAL FEES ENCLOSED =		**$1,110.00**	
		Amount to be: refunded	$
		charged	$

a. ☐ A check in the amount of ________ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 06-1500 in the amount of $1,110.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 06-1500 A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

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Sujatha S

SIGNATURE

Sujatha Subramaniam

NAME

48,739

REGISTRATION NUMBER

December 5, 2001

DATE

CERTIFICATE OF MAILING BY EXPRESS MAIL

I hereby certify that this correspondence is being deposited with the United States Postal Service as "Express Mail Post Office to Addressee" service under 37 C.F.R. 1.10 and is addressed to: U.S. Patent and Trademark Office, P.O. Box 2327, BOX PATENT APPLICATION, Arlington, VA 22202 on
12/05/2001.

By Vyatha

Attorney Docket No.: 10541-824

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Garry Royston Fish		)	
International Application No.:	PCT/GB00/02152	)	**PRELIMINARY**
Filed:	June 5, 2000	)	**AMENDMENT**
For: HEAT EXCHANGER TUBE		)	

PRELIMINARY AMENDMENT UNDER 37 C.F.R. §1.115

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

Please amend the above-identified application as follows:

IN THE SPECIFICATION

Please substitute the specification in accordance with 37 C.F.R. §1.121(b)(3). A marked up copy of the specification showing the changes is attached as Appendix A. The substitute specification without claims is attached as Appendix B.

IN THE CLAIMS

Please amend Claims 1-14 as shown in Appendix C. A clean version of the Claims is as follows:

1. (Amended) A tube for conveying coolant through a heat exchanger, the tube having a flattened cross-section with two major opposing walls comprising: an

internal projections on the two major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, such that each projection extends across less than 30% of the width of the tube and an area of the tube walls having projections amounts to less than 7.5% of a total area of the tube walls.

2. (Amended) The tube as claimed in Claim 1, wherein the area of the walls having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. (Amended) The tube as claimed in Claim 1, wherein the area of the tube walls having projections amounts to less than 5% of the total area of the tube walls.

4. (Amended) The tube as claimed in Claim 1, wherein the area of the tube walls having projections amounts to approximately 2.5% of the total area of the tube walls.

5. (Amended) The tube as claimed in Claim 1, wherein the projections are in the form of dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. (Amended) The tube as claimed in Claim 1, wherein the projections are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. (Amended) The tube as claimed in Claim 6, wherein the line of projections on one opposing wall extends in a diagonally opposite direction to the line of projections on the other opposing wall.

8. (Amended) The tube as claimed in Claim 6, wherein the projections on one opposing wall are greater in number than the projections on the other opposing wall, and the projections on the one wall are offset across the width of the tube from the projections on the other opposing wall.

9. (Amended) The tube as claimed in Claim 1, wherein the projections are in the form of indentations punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. (Amended) The tube as claimed in Claim 1, wherein the projections are generally square or rectangular in plan view.

11. (Amended) The tube as claimed in Claim 1 any preceding claim, wherein the projections have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. (Amended) The tube as claimed in Claim 1, wherein the depth of the projections is between 35 and 50% of the internal diameter of the tube.

13. (Amended) A heat exchanger having a heat exchange core comprising:

a plurality of parallel coolant tubes;

heat exchange fins separating the coolant tubes;

wherein each of the tubes has a flattened cross-section with two major opposing walls; and

internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, such that each projection extends across less than 30% of the width of the tube and an area of the tube walls having projections amounts to less than 7.5% of a total area of the tube walls.

14. (Amended) A method of operating a heat exchanger in which coolant is conveyed through tubes, wherein each tube has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, characterised in that the projections extend into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger, and wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.

Add new claims 16-25 as follows:

16. (New) The heat exchanger as claimed in Claim 13, wherein the area of the tube walls having projections amounts to less than 5% of the total area of the tube walls.

17. (New) The heat exchanger as claimed in Claim 13, wherein the area of the tube walls having projections amounts to approximately 2.5% of the total area of the tube walls.

18. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

19. (New) The heat exchanger as claimed in Claim 13, wherein the projections are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

20. (New) The heat exchanger as claimed in Claim 19, wherein the line of projections on one opposing wall extends in a diagonal opposite direction to the line of projections on the other opposing wall.

21. (New) The heat exchanger as claimed in Claim 19, wherein the projections on one opposing wall are greater in number than the projections on the other opposing wall, and the projections on the one wall are offset across the width of the tube from the projections on the other opposing wall.

22. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of indentations punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

23. (New) The heat exchanger as claimed in Claim 13, wherein the projections are generally square or rectangular in plan view.

24. (New) The heat exchanger as claimed in Claim 13, wherein the projections have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

25. (New) The heat exchanger as claimed in Claim 13, wherein the depth of the projections is between 35 and 50% of the internal diameter of the tube.

REMARKS

Applicant submits that by this Preliminary Amendment, Claims 1-14 have been amended. New claims 16-25 have been added. Applicant submits that no new matter has been added by way of this amendment.

Applicant is also submitting a substitute specification pursuant to 37 C.F. R. §1.121(b)(3). Applicant states that the substitute specification includes no new matter.

CONCLUSION

Applicant requests that you charge Deposit Account No. 06-1500 for any further fees which may be due. A duplicate copy of this document is enclosed for that purpose. Should the Examiner have any questions regarding this application, the Examiner is requested to call the undersigned.

Respectfully submitted,

Dated: December 5th, 2001

By: Sujatha S
SUJATHA SUBRAMANIAM
Reg. No. 48,739

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(734) 302-6000

CONCLUSION

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10/009504
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APPENDIX A

HEAT EXCHANGER TUBE.

TECHNICAL FIELD OF THE INVENTION

This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers[,]. [for example vehicle radiators, or through any tube/fin heat exchanger such as a heater core.]

BACKGROUND OF THE INVENTION

US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

SUMMARY OF THE INVENTION

[I have now surprisingly found that] <u>The present invention provides for a</u> better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production of turbulence in the coolant, [whilst] <u>while at the same time</u> producing the necessary mixing of the coolant under laminar flow conditions. <u>In this invention</u> [M] <u>m</u>ixing means that

coolant which at one moment is in contact with the tube wall moves from that position into the centre of the tube, and vice versa[,]. [t]This process is taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, [it was seen necessary to encourage turbulence] in order to achieve this desirable uniform temperature distribution it was important to create turbulence.

In addition to [giving] achieving good mixing of the hot coolant in the tube, the absence of turbulence in [my invention] the present invention can also reduce the back pressure which the coolant experiences [in] by flowing through the tubes. As a result, better heat transfer is achieved.

According to the invention [there is provided] a tube for conveying coolant through a heat exchanger is provided[,]. [t]The tube [having] has a flattened cross-section with two major opposing walls. [and] Further, the tube has internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube[,]. [wherein] [e]Each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible [(in comparison to the prior art)] to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant[,]. [whilst still obtaining] At the same time, it is also possible to obtain the necessary mixing of the coolant.

The projections are preferably dimples formed in the tube walls[,]. [t]The dimples [having] have substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

Preferably, the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections

amounts to less than 5%, and the best results are obtained [by the inventor at the time of preparation of this specification are achieved] when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

The projections on one wall can be greater in number than the projections on the other (opposing) wall.

The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy. [and] [t]The tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld[,]. [with] [t]The weld seam is preferably running along one edge of the tube which joins the two major walls, after the tube has been flattened. Alternatively [However], the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes [is also] are possible. For example, the projections may have a length greater than their width[,]. [and] [i]In this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which

are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the [tube/] header tank joint area.

The invention also provides for a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins[,]. [wherein] [e]Each of the tubes [has] have a flattened cross-section with two major opposing walls. [and] The tubes further have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube[,]. [wherein] [e]Each of the projections extend[s] across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes[,]. [wherein] [e]Each tube has a flattened cross-section with two major opposing walls. [and] The tubes have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

Figure 2 is a cross section through a prior art heat exchanger tube;

Figure 3 is a perspective view of a tube in accordance with the invention;

Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

Figure 6 is a plan view of the tube of Figure 3;

Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

Figure[s] 8 [and 9 are] is section[s] taken on the lines VIII-VIII [and IX-IX] from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14. [and] The fins 16 are in heat exchange contact with the tubes 14. In use, coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16[, and] [t]The heat of the coolant in the tubes 14 is [given up to] exchanged with the air passing through the fins 16.

Figure 2 shows an enlarged cross sectional view through [a] tubes 14. The tubes 14 [is] are formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes 14 are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. [Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.]

The tubes 14 as shown in Figure 2 has a smooth internal bore 24. If coolant flows along [a] tubes 14 with a smooth internal bore, the coolant flow along the tubes tend[s] to be laminar or streamline flow. In this case, there will be a region at the centre of the flow (indicated [in] by the dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube[, and]. Therefore, this region of coolant is [therefore] insulated from the heat exchange taking place at the tube walls [by the body of coolant

between the region and the tube walls]. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which [does] enhances mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28[, and whilst]. The coolant while passing through the tubes 14 will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V–IV,V [from] of Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tubes 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45°

to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figure[s] 8 [and S] where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations[,]. [but it is preferable that] <u>Preferably,</u> the indentations will be positioned in a regular array rather than a random array. The intention however is that the presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection <u>30</u>. However, since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection. [whereupon diversion and therefore coolant mixing will take place again.]

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally [(as

shown in Figure 8)] and also perpendicularly [(as shown in Figure 9)] to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs, and
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

The foregoing discussion discloses and describes a preferred embodiment of the invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that changes and modifications can be made to the invention without departing from the true spirit and fair scope of the invention as defined in the following claims.

PTO/PCT Rec'd 05 DEC 2001

10/009504

10541-824

APPENDIX B

HEAT EXCHANGER TUBE

TECHNICAL FIELD OF THE INVENTION

[0001] This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers.

BACKGROUND OF THE INVENTION

[0002] US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

[0003] US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

SUMMARY OF THE INVENTION

[0004] The present invention provides for a better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production of turbulence in the coolant, while at the same time producing the necessary mixing of the coolant under laminar flow conditions. In this invention mixing means that coolant which at one moment is in contact with the tube wall

moves from that position into the centre of the tube, and vice versa. This process is taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, in order to achieve this desirable uniform temperature distribution it was important to create turbulence.

[0005] In addition to achieving good mixing of the hot coolant in the tube, the absence of turbulence in the present invention can also reduce the back pressure which the coolant experiences by flowing through the tubes. As a result, better heat transfer is achieved.

[0006] According to the invention a tube for conveying coolant through a heat exchanger is provided. The tube has a flattened cross-section with two major opposing walls. Further, the tube has internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube. Each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

[0007] By reducing the number of projections to this level it is possible to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant. At the same time, it is also possible to obtain the necessary mixing of the coolant.

[0008] The projections are preferably dimples formed in the tube walls. The dimples have substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

[0009] Preferably, the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results are obtained when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

[0010] For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending

across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

[0011] Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

[0012] The projections on one wall can be greater in number than the projections on the other (opposing) wall.

[0013] The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy. The tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld. The weld seam is preferably running along one edge of the tube which joins the two major walls, after the tube has been flattened. Alternatively, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

[0014] The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes are possible. For example, the projections may have a length greater than their width. In this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

[0015] Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the header tank joint area.

[0016] The invention also provides for a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins. Each of the tubes have a flattened cross-section with two major opposing walls. The tubes further have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube. Each of the projections extend across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

[0017] In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes. Each tube has a flattened cross-section with two major opposing walls. The tubes have internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

[0018] The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

[0020] Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

[0021] Figure 2 is a cross section through a prior art heat exchanger tube;

[0022] Figure 3 is a perspective view of a tube in accordance with the invention;

[0023] Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

[0024] Figure 6 is a plan view of the tube of Figure 3;

[0025] Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

[0026] Figure 8 is section taken on the lines VIII-VIII from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0027] In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14. The fins 16 are in heat exchange contact with the tubes 14. In use, coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16. The heat of the coolant in the tubes 14 is exchanged with the air passing through the fins 16.

[0028] Figure 2 shows an enlarged cross sectional view through tubes 14. The tubes 14 are formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes 14 are formed from initially flat material which is welded together by a longitudinal weld indicated at 22.

[0029] The tubes 14 as shown in Figure 2 has a smooth internal bore 24. If coolant flows along tubes 14 with a smooth internal bore, the coolant flow along the tubes tend to be laminar or streamline flow. In this case, there will be a region at the centre of the flow (indicated by the dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube. Therefore, this region of coolant is insulated from the heat exchange taking place at the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

[0030] The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which enhances mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

[0031] Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28. The coolant while passing through the tubes 14 encounter projections 30a,

30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

[0032] Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V–IV,V of Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

[0033] It will be noted from Figure 3 that the greater part of the surface of the tubes 14 is plain and not provided with indentations.

[0034] Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with indentations on the upper (as seen in the Figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

[0035] It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figure 8 where the arrows show streamline flow around and over the projections.

[0036] Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

[0037] The invention is not limited to any particular form or arrangement of indentations. Preferably, the indentations will be positioned in a regular array rather than a random array. The intention however is that the presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

[0038] Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection 30. However, since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection.

[0039] Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally and also perpendicularly to the major plane of the tube.

[0040] The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

[0041] In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs, and
- reducing potential leak paths between tube indentations and headers.

[0042] Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a

minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

[0043] Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

[0044] The foregoing discussion discloses and describes a preferred embodiment of the invention. One skilled in the art will readily recognize from such discussion, and from the accompanying drawings and claims, that changes and modifications can be made to the invention without departing from the true spirit and fair scope of the invention as defined in the following claims.

10/009504
JC13 Rec'd PCT/PTO 05 DEC 2001

Appendix C

In the Claims:

1. (Amended) A tube [(14)] for conveying coolant through a heat exchanger [(10)], the tube having a flattened cross-section with two major opposing walls comprising: an [and] internal projections [(30)] on the two major opposing walls [(18,20)], the projections extending into [the] an internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, [characterised in] such that each projection [(30)] extends across less than 30% of the width of the tube and [the] an area of the tube walls [(18,20)] having projections amounts to less than 7.5% of [the] a total area of the tube walls.

2. (Amended) [A] The tube as claimed in Claim 1, wherein the area of the [tube] walls [(18,20)] having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. (Amended) [A] The tube as claimed in Claim 1 [or Claim 2], wherein the area of the tube walls [(18,20)] having projections amounts to less than 5% of the total area of the tube walls.

4. (Amended) [A] The tube as claimed in Claim 1, [or Claim 2] wherein the area of the tube walls [(18,20)] having projections amounts to approximately 2.5% of the total area of the tube walls.

5. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are in the form of dimples [(32)] formed in the tube walls [(18,20)], the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. (Amended) [A] The tube as claimed in Claim 6, wherein the line of projections [(30)] on one opposing wall [(18)] extends in a diagonally opposite direction to the line of projections [(30)] on the other opposing wall [(20)].

8. (Amended) [A] The tube as claimed in Claim 6 [or Claim 7], wherein the projections [(30)] on one opposing wall [(18)] are greater in number than the projections on the other opposing wall [(20)], and the projections on the one wall [(18)] are offset across the width of the tube from the projections on the other opposing wall [(20)].

9. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are in the form of indentations [(32)] punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. (Amended) [A] The tube as claimed in Claim 1 [any preceding claim], wherein the projections [(30)] are generally square or rectangular in plan view.

11. (Amended) [A] The tube as claimed in Claim 1 any preceding claim, wherein the projections [(30)] have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. (Amended) [A] The tube as claimed in Claim 1 [any one of the preceding claims], wherein the depth of the projections [(30)] is between 35 and 50% of the internal diameter of the tube.

13. (Amended) A heat exchanger having a heat exchange core [(10)] comprising:

a plurality of parallel coolant tubes; [(14) separated by]

heat exchange fins [(16),] separating the coolant tubes;

wherein each of the tubes [(14)] has a flattened cross-section with two major opposing walls [(18,20)]; and

internal projections [(30)] on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, [characterised in] such that each projection [(30)] extends across less than 30% of the width of the tube [(14)] and [the] an area of the tube walls having projections amounts to less than 7.5% of [the] a total area of the tube walls.

14. (Amended) A method of operating a heat exchanger in which coolant is conveyed through tubes [(14)], wherein each tube [(14)] has a flattened cross-section with two major opposing walls [(18,20)] and internal projections [(30)] on the major opposing walls, characterised in that the projections [(30)] extend into the internal cross-sectional area of the tube [(14)] to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger, and wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls.[.]

Add new claims 16-25 as follows:

16. (New) The heat exchanger as claimed in Claim 13, wherein the area of the tube walls having projections amounts to less than 5% of the total area of the tube walls.

17. (New) The heat exchanger as claimed in Claim 13, wherein the area of the tube walls having projections amounts to approximately 2.5% of the total area of the tube walls.

18. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

19. (New) The heat exchanger as claimed in Claim 13, wherein the projections are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

20. (New) The heat exchanger as claimed in Claim 19, wherein the line of projections on one opposing wall extends in a diagonally opposite direction to the line of projections on the other opposing wall.

21. (New) The heat exchanger as claimed in Claim 19, wherein the projections on one opposing wall are greater in number than the projections on the other opposing wall, and the projections on the one wall are offset across the width of the tube from the projections on the other opposing wall.

22. (New) The heat exchanger as claimed in Claim 13, wherein the projections are in the form of indentations punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

23. (New) The heat exchanger as claimed in Claim 13, wherein the projections are generally square or rectangular in plan view.

24. (New) The heat exchanger as claimed in Claim 13, wherein the projections have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

25. (New) The heat exchanger as claimed in Claim 13, wherein the depth of the projections is between 35 and 50% of the internal diameter of the tube.

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HEAT EXCHANGER TUBE

This invention relates to heat exchangers for reducing the temperature of the coolant which circulates in a heat exchange circuit. In particular the present invention relates to tubes for conveying coolant through such heat exchangers, for example vehicle radiators, or through any tube/fin heat exchanger such as a heater core.

US patent 4 470 452 discloses a radiator tube which is constructed so as to produce turbulence in the coolant flow to improve the heat exchange characteristics between the coolant and the air which, in use, flows through the radiator and past the tubes. In that specification the radiator tubes disclosed have flow diverting members placed along the length of each principal heat transfer surface, with the principal heat transfer surfaces being bowed outwardly. The flow diverting members (which actually take the form of indentations or dimples pressed into the walls of the tubes) are present to provide turbulence in the coolant as it flows along the tube.

US Patent 2 017 201 describes a condenser tube which has a pair of parallel walls and inwardly extending transverse indentations which form transverse restrictions in the passage through the tube offset from the central plane of the tube. The presence of these indentations or ribs produces turbulence of the liquid circulating through the tubes.

I have now surprisingly found that better heat exchange between the coolant and the air can be achieved by substantially reducing, or even preventing, the production

of turbulence in the coolant, whilst producing the necessary mixing of the coolant under laminar flow conditions. Mixing means that coolant which at one moment is in contact with the tube wall moves from that position into the centre of the tube, and vice versa, this process taking place continuously to encourage uniform temperature distribution throughout the coolant. In the prior art, it was seen necessary to encourage turbulence to achieve this desirable uniform temperature distribution.

In addition to giving good mixing of the hot coolant in the tube, the absence of turbulence in my invention can also reduce the back pressure which the coolant experiences in flowing through the tubes. As a result, better heat transfer is achieved.

According to the invention there is provided a tube for conveying coolant through a heat exchanger, the tube having a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

By reducing the number of projections to this level it is possible (in comparison to the prior art) to reduce the resistance to coolant flow through the tube, and thus to reduce the back pressure experienced by the coolant, whilst still obtaining the necessary mixing of the

coolant.

The projections are preferably dimples formed in the tube walls, the dimples having substantially equal dimensions in the direction of flow and transverse to the direction of flow. This ensures that the coolant flow is diverted in two planes, namely over the projections and around the projections, which produces particularly effective mixing of the coolant under laminar flow conditions.

Preferably the area of the tube walls occupied by projections amounts to less than 7.5% but more than 1% of the total area of the tube walls. Better results are achieved if the area of the tube walls occupied by projections amounts to less than 5%, and the best results obtained by the inventor at the time of preparation of this specification are achieved when the area of the tube walls occupied by projections amounts to approximately 2.5% of the total area of the tube walls.

For reasons of manufacturing practicality the projections will normally be formed in a regular or repeating pattern. The projections may be arranged in groups and within each group the projections can be arranged on a line extending across the tube. The projections on one wall can extend in a diagonally opposite direction to the line of projections on the other (opposing) wall.

Considered along an imaginary line which runs parallel to the length of the tube, projections on one wall may alternate with projections on the other wall. The alternating projections may be in line or may be offset relative to an imaginary line parallel to the tube axis.

The projections on one wall can be greater in number than the projections on the other (opposing) wall.

The tube may be formed from any suitable material, for example metal or a plastics material. A preferred material is aluminium or an aluminium alloy and the tube is preferably formed from sheet material and is formed into a tube by a longitudinally extending weld, with the weld seam running along one edge of the tube which joins the two major walls, after the tube has been flattened. However, the tube could be formed by other means, for example extrusion or pre-casting, and the weld seam of the tube (if welded) could extend in other directions.

The projections preferably take the form of dimples or indentations formed in the outer surface of the tube walls, to appear as projections in the internal cross-section of the tube. The projections can be generally square in plan view, but a wide variety of non square shapes is also possible. For example the projections may have a length greater than their width, and in this case the length of the projections can be set at an angle to the length of the tube. Although it is preferred that the projections are generally square or rectangular in plan view, there may be benefits from having projections which are oval or circular in plan view; for example circular indentations may help promote laminar flow while still permitting mixing. Oval indentations may help promote directional flow depending on the orientation of the axes.

Ends of each tube can be free from any indentations formed in the external tube surface, so that the tube ends can be

reliably sealed into heat exchanger header tanks without any potential leak paths resulting from indentations lying within the tube/header tank joint area.

The invention also provides a heat exchanger having a heat exchange core comprising a plurality of parallel coolant tubes separated by heat exchange fins, wherein each of the tubes has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, wherein each projection extends across less than 30% of the width of the tube and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

In another aspect, the invention provides a method of operating a heat exchanger in which coolant is conveyed through tubes, wherein each tube has a flattened cross-section with two major opposing walls and internal projections on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger.

The laminar flow preferably follows a path which is diverted from wall to wall and from side to side between the tube walls. This ensures excellent mixing of the coolant without disturbing the laminar nature of the flow.

The invention will now be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a scrap view showing one part of a conventional heat exchanger construction;

Figure 2 is a cross section through a prior art heat exchanger tube;

Figure 3 is a perspective view of a tube in accordance with the invention;

Figures 4 and 5 show alternative cross-sections on the line IV,V-IV,V;

Figure 6 is a plan view of the tube of Figure 3;

Figure 7 is a plan view of part of an alternative form of tube in accordance with the invention; and

Figures 8 and 9 are sections taken on the lines VIII-VIII and IX-IX from Figure 3 to illustrate flow patterns in the tubes in accordance with the invention.

In Figure 1 a typical motor vehicle radiator is shown. The radiator has a heat exchange core or matrix 10 connected to a header tank 12. The core 10 consists of a number of parallel coolant tubes 14 with heat exchange fins 16 of concertina form mounted between the tubes 14 and in heat exchange contact with the tubes. In use,

coolant flows into the header tank 12 and from the header tank through the tubes 14 to a similar header tank at the opposite end of the radiator. Air moves through the fins 16, and the heat of the coolant in the tubes 14 is given up to the air passing through the fins.

Figure 2 shows an enlarged cross sectional view through a tube 14. The tube is formed from thin sheet material of flattened cross-section but with slightly bowed major faces 18 and 20. The tubes are formed from initially flat material which is welded together by a longitudinal weld indicated at 22. Reference should be had to US Patent 4 470 452 in connection with the bowing of the major faces 18 and 20, which is somewhat exaggerated in Figure 2.

The tube 14 shown in Figure 2 has a smooth internal bore 24. If coolant flows along a tube 14 with a smooth internal bore, the coolant flow along the tube tends to be laminar or streamline flow. In this case there will be a region at the centre of the flow (indicated in dotted lines 26 in Figure 2) where the coolant has no inducement to make contact with the walls of the tube, and this region of coolant is therefore insulated from the heat exchange taking place at the tube walls by the body of coolant between the region and the tube walls. It is therefore clearly desirable to interfere with the coolant flow through the tube and to provide mixing of the coolant as it passes through the tubes, so that heat exchange takes place with all of the coolant, and uniform temperature distribution throughout the fluid is promoted.

The conventional approach to ensure mixing is to use so-called turbulator radiator tubes, one example of which is shown in US patent 4 470 452. Turbulator radiator tubes, as their name implies, produce turbulence in the flow which does enhance mixing. However the production of turbulence results in a resistance to flow which detracts from the performance.

Figure 3 is a perspective view of a tube in accordance with the invention. It is intended that coolant will flow through the tube as indicated by an arrow 28, and whilst passing through the tube will encounter projections 30a, 30b (Figures 4 and 5) which are formed on the internal wall of the tube by indentations pressed from the outside wall of the tube. The indentations are indicated by reference numeral 32 in Figure 3, and the corresponding projections by 30a and 30b in Figures 4 and 5.

Figures 4 and 5 illustrate alternative forms of indentation. In Figure 4 the indentations are round-bottomed, and in Figure 5 the indentations have a trapezoid cross-section. These sections are taken on the lines IV,V-IV,V from Figure 3. The preferred depth d for the indentations 30a, 30b is between 35 and 50% of the internal tube height.

It will be noted from Figure 3 that the greater part of the surface of the tube 14 is plain and not provided with indentations.

Although Figure 3 shows only side of the tube, the other side of the tube will also be provided with corresponding indentations 32. Figure 6 illustrates this with

indentations on the upper (as seen in the figure) face of the tube being shown in solid lines with the indentations on the lower or underneath side of the tube being shown in dotted outline. The indentations on the upper face extend along a line which makes an angle of approximately 45° to the length of the tube, and the indentations on the lower face are arranged in a corresponding manner, but along a line which makes an opposite angle of 45° to that of the indentations on the upper face. The preferred range for such angles is 30 to 60°.

It will be noted that, in passing through the bore of the tube, the coolant flow will encounter first a projection from the lower face of the tube then a projection from the upper face then a projection from the lower face and so on. This ensures that the flow is mixed both in a direction at right angles to the major plane of the tube as well as in a transverse direction across the major plane of the tube. This is shown in Figures 8 and S where the arrows show streamline flow around and over the projections.

Figure 7 shows a smaller section of an alternative form of tube with indentations 132 which are elongated in form and have their long axis angled to the direction of coolant flow 28. As in Figure 6, the corresponding indentations on the lower face have the same form but follow a line which crosses the line of indentations on the upper face.

The invention is not limited to any particular form or arrangement of indentations, but it is preferable that the indentations will be positioned in a regular array rather than a random array. The intention however is that the

presence of the indentations/projections in the tube should interrupt the coolant flow sufficiently to ensure mixing of the coolant within each tube but should not interfere with the flow so drastically as to prevent the flow being generally laminar or streamline in form.

Figure 8 illustrates the nature of this flow within a tube 14 past projections 30. When the incoming laminar coolant flow is interrupted by a projection 30, the flow will divert and pass around the projection. However since the distance between projections (seen in the longitudinal direction) is comparatively long, there will be sufficient time for the flow to resume its laminar form before it encounters the next projection whereupon diversion and therefore coolant mixing will take place again.

Figure 8 shows the flow pattern in one plane. It must however be appreciated that the flow is also constrained by the presence of the projections both above and below the plane shown in Figure 8, and therefore the diversion of the flow when encountering a projection will take place both laterally (as shown in Figure 8) and also perpendicularly (as shown in Figure 9) to the major plane of the tube.

The ends of each tube will preferably be formed without any indentations, so that those ends can be reliably sealed to a header plate 34 (Figure 1) where the tubes 14 communicate with the header tank 12. The fewer the indentations the lower the probability of leaks resulting from indentations coming in contact with the header joints.

In comparison with turbulator tubes as described in US patent 4 470 452, the number and area of projections which interfere with the coolant flow through the tubes is substantially reduced. This has benefits in

- increasing heat transfer between the coolant and the fins 16,
- reducing back pressure and therefore facilitating coolant flow through the tubes,
- simplifying manufacture and reducing tooling costs
- reducing potential leak paths between tube indentations and headers.

Typical tube dimensions for a radiator for a passenger vehicle with an internal combustion engine have a major axis dimension of about 26 mm and a minor axis dimension of about 2 mm. Each indentation 32 can have a dimension of 1-2 mm^2, and the area of the tube covered by indentations can amount to about 2.5% of the total tube surface area.

Tests can be carried out to determine the optimum configuration and form of the indentation, either through practical tests with different samples, or through computer modelling.

Claims

1. A tube (14) for conveying coolant through a heat exchanger (10), the tube having a flattened cross-section with two major opposing walls and internal projections (30) on the major opposing walls (18,20), the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube and the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls.

2. A tube as claimed in Claim 1, wherein the area of the tube walls (18,20) having projections amounts to less than 7.5% of the total area of the tube walls and more than 1% of the total area of the tube walls.

3. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to less than 5% of the total area of the tube walls.

4. A tube as claimed in Claim 1 or Claim 2, wherein the area of the tube walls (18,20) having projections amounts to approximately 2.5% of the total area of the tube walls.

5. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of dimples (32) formed in the tube walls (18,20), the dimples having substantially equal dimensions in the direction of coolant flow and transverse to the direction of flow.

6. A tube as claimed in any preceding claim, wherein the projections (30) are arranged in groups and within each group, the projections are arranged on a line extending diagonally across the tube.

7. A tube as claimed in Claim 6, wherein the line of projections (30) on one opposing wall (18) extends in a diagonally opposite direction to the line of projections (30) on the other opposing wall (20).

8. A tube as claimed in Claim 6 or Claim 7, wherein the projections (30) on one opposing wall (18) are greater in number than the projections on the other opposing wall (20), and the projections on the one wall (18) are offset across the width of the tube from the projections on the other opposing wall (20).

9. A tube as claimed in any preceding claim, wherein the projections (30) are in the form of indentations (32) punched out from one surface of the tube to appear as projections in the internal cross-section of the tube.

10. A tube as claimed in any preceding claim, wherein the projections (30) are generally square or rectangular in plan view.

11. A tube as claimed in any preceding claim, wherein the projections (30) have a length greater than their width, and the length of the projections is set at an angle to the length of the tube.

12. A tube as claimed in any one of the preceding claims, wherein the depth of the projections (30) is between 35 and 50% of the internal diameter of the tube.

13. A heat exchanger having a heat exchange core (10) comprising a plurality of parallel coolant tubes (14) separated by heat exchange fins (16), wherein each of the tubes (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, the projections extending into the internal cross-sectional area of the tube to interfere with the flow of coolant along the tube, characterised in that each projection (30) extends across less than 30% of the width of the tube (14) and the area of the tube walls having projections amounts to less than 7.5% of the total area of the tube walls.

14. A method of operating a heat exchanger in which coolant is conveyed through tubes (14) .wherein each tube (14) has a flattened cross-section with two major opposing walls (18,20) and internal projections (30) on the major opposing walls, characterised in that the projections (30) extend into the internal cross-sectional area of the tube (14) to an extent such that laminar coolant flow is maintained within the tube over the normal operating range of the heat exchanger and wherein the laminar flow follows a path which is diverted from wall to wall and from side to side between the tube walls..

Fig. 1

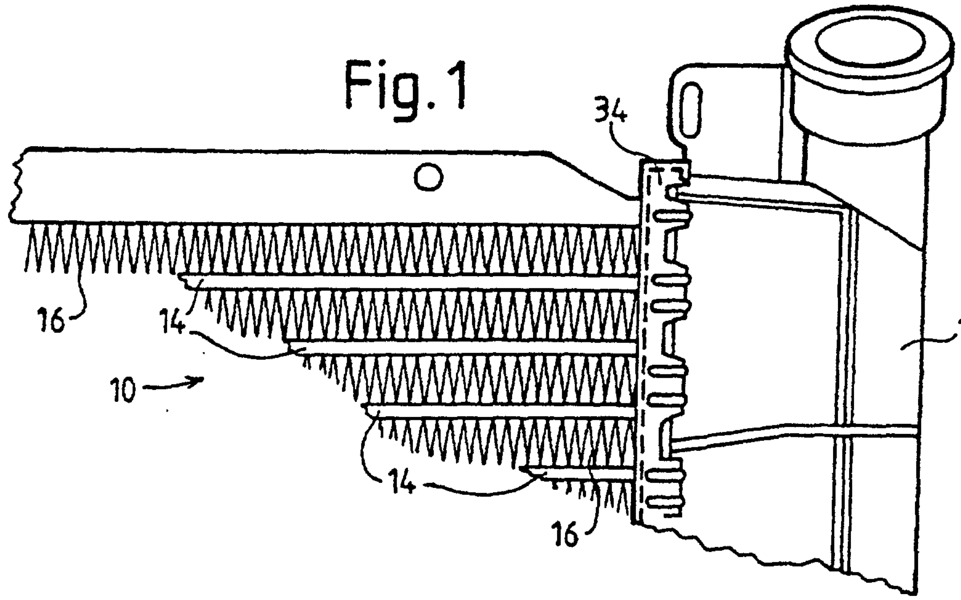
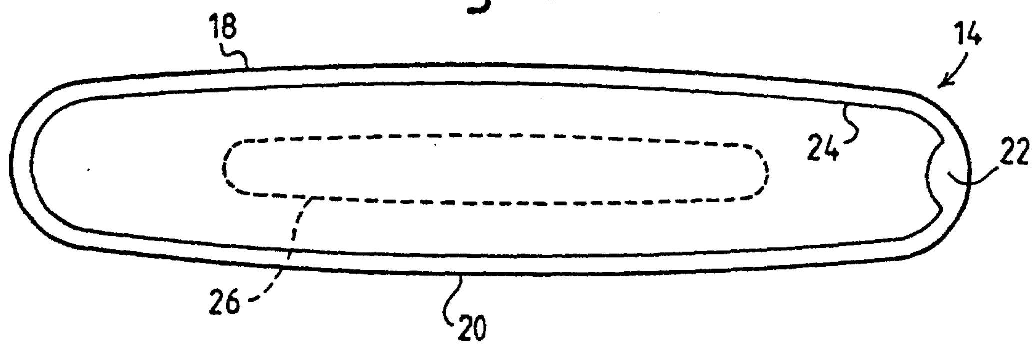


Fig. 2



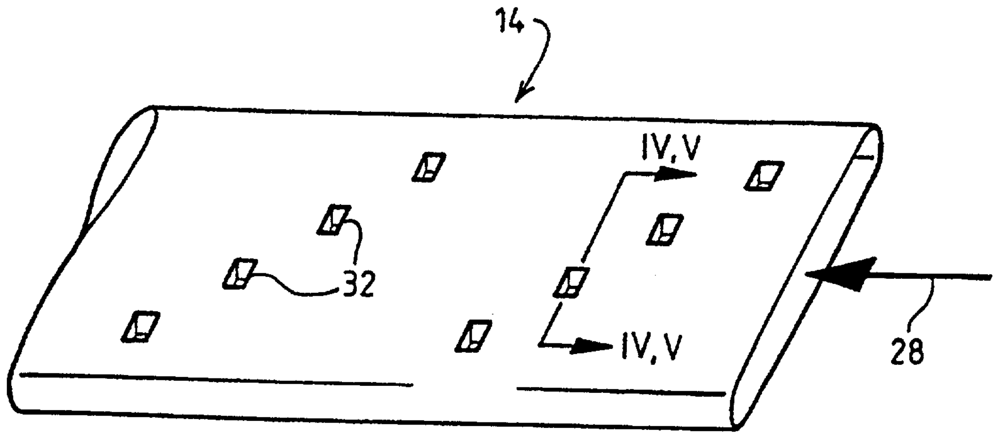
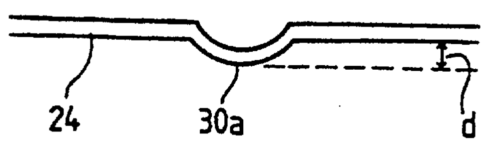


Fig. 3

Fig. 4



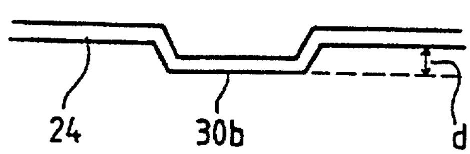


Fig. 5

3/3

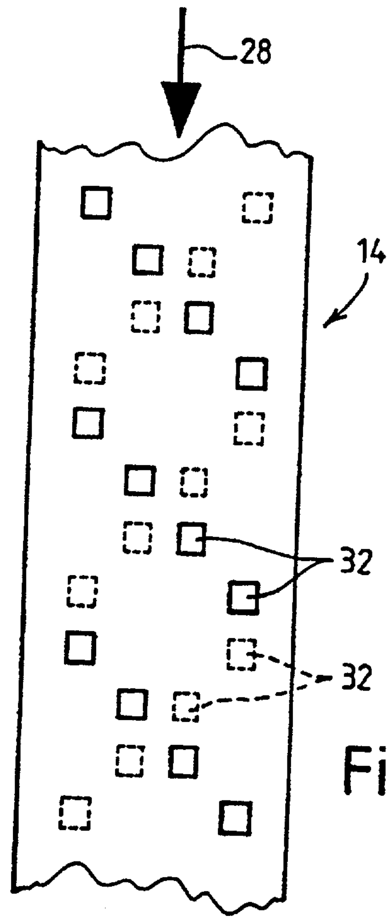


Fig. 6

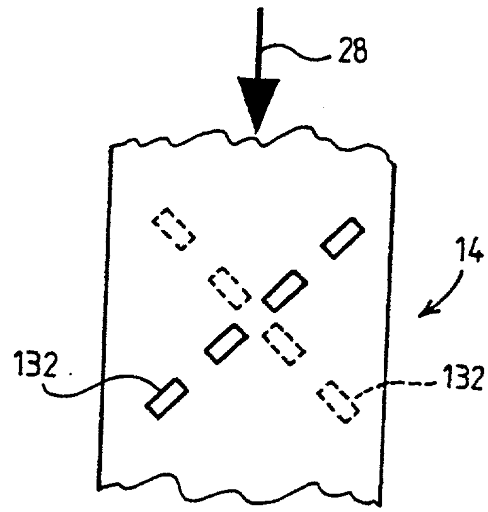
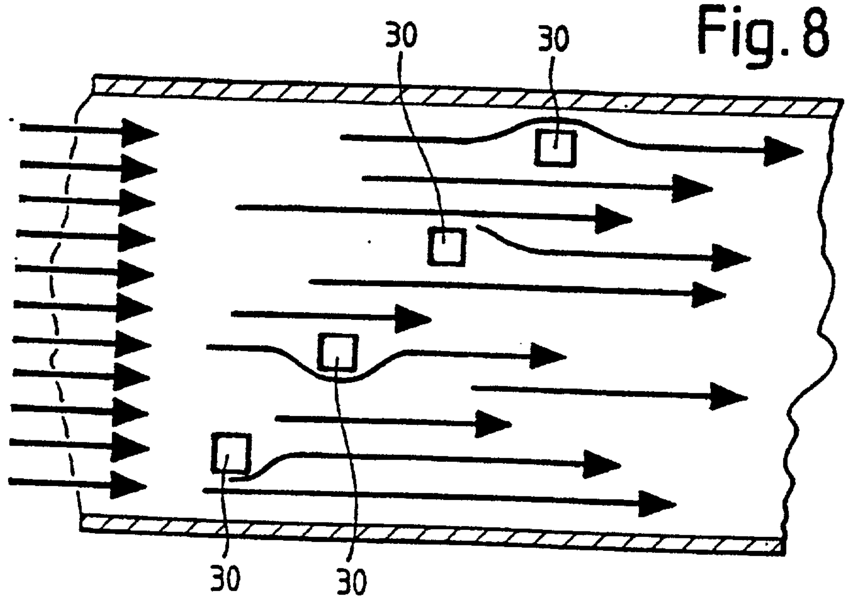


Fig.7

Fig.8



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Attorney Docket No.: 10541-824
Visteon Case No.: 199-0863

DECLARATION AND POWER OF ATTORNEY ORIGINAL APPLICATION

As a below named inventor, I hereby declare:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor or an original, first and joint inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled:

HEAT EXCHANGE TUBE

the specification of which (check one)

☐ is attached hereto.

☒ was filed on December 5, 2001 as United States Application Serial No. 10/009,504 and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge my duty to disclose to the United States Patent and Trademark Office all information that I know to be material to the patentability of this application as defined in Title 37 C.F.R. § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s):			Priority Not Claimed
PCT/GB00/02152 (Number)	Great Britain (Country)	5 June 2000 (Filing Date)	☐
(Number)	(Country)	(Filing Date)	☐
(Number)	(Country)	(Filing Date)	☐

I hereby claim the benefit under 35 U.S. C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

I hereby claim the benefit under 35 U.S.C. Section 120 of any United States applications(s), or Section 365(c) of any PCT International Application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorneys, agents, and each shareholder, attorney of counsel, associate, and employee of Brinks Hofer Gilson & Lione, who is a registered Patent Attorney or registered Patent Agent, my attorney with full power of substitution and revocation to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith and to act on my behalf before the competent International Authorities in connection with any and all international applications filed by me.

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